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(56) Documents Cited
GB 2356629 A
GB 2322631 A
DE 010030459 A
JP 550069683 A
GB 2327682 A
DE 019720296 A
DE 010020061 A

(58) Field of Search
UK CL (Edition V) **C4X**
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(54) Abstract Title
Liquid crystalline medium and liquid crystal display

(57) A liquid crystalline medium comprising a chiral component A, preferably selected from the compound of formulae I, I' and I'' defined in the description, and a dielectrically positive component C. The liquid crystalline medium preferably also contains a bimesogenic component B of formula II, a dielectrically negative component D and a dielectrically neutral component E. These liquid crystalline media are of use in liquid crystal devices, in particular electro-optical devices such as displays, especially of the flexoelectric type.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 387 603 A

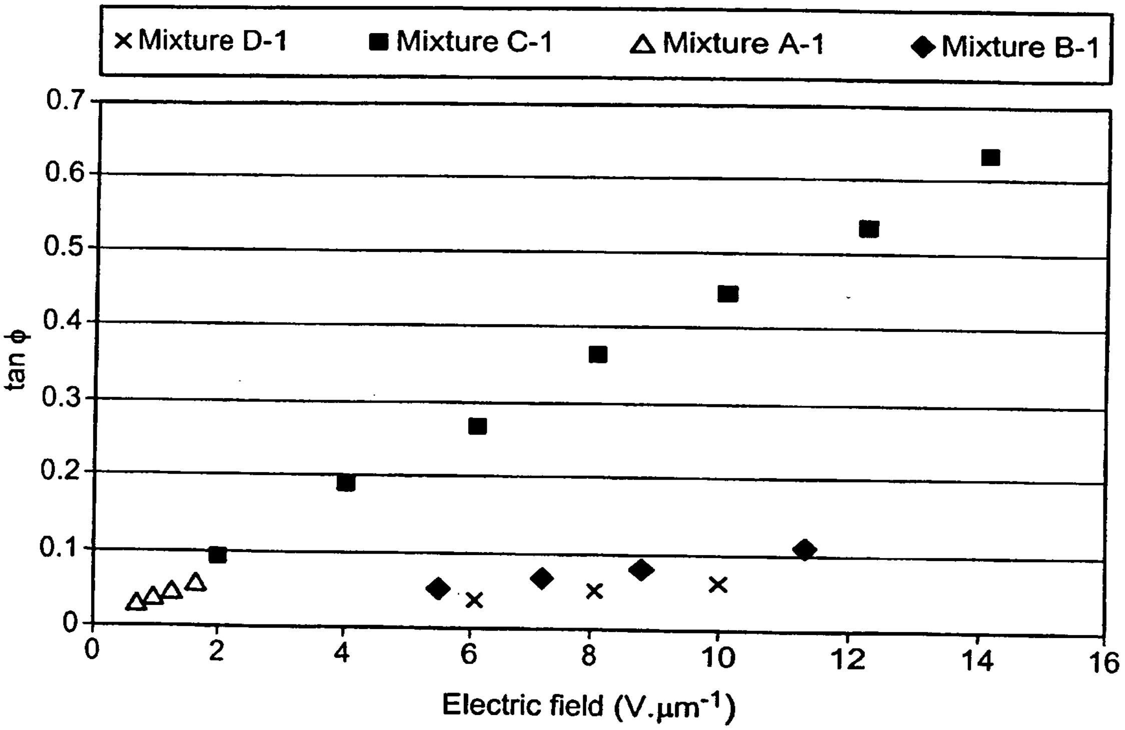

× Mixture D-1
■ Mixture C-1
△ Mixture A-1
◆ Mixture B-1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
tan φ
0
2
4
6
8
10
12
14
16
Electric field (V.μm⁻¹)

FIG. 1

2387603

Liquid Crystalline Medium
and Liquid Crystal Display

Field of the invention

The present invention relates to liquid crystalline media and to liquid crystal displays comprising these media, especially to displays exploiting the flexoelectric effect in chiral nematic liquid crystals and in particular to displays operating in the uniformly lying helix mode.

State of the art and problem to be solved

The flexoelectric effect is well known since quite some time from the paper by Patel and Meyer (Phys. Rev. Lett. **58** (15), p. 1538-1540 (1987)) and has more recently been reviewed by Rudquist et al. (Liq. Cryst. **22** (4), 445-449 (1997).

The uniform lying helix (ULH) texture is realized using a chiral nematic liquid crystal with a short pitch, typically in the range from 0.2 µm to 1 µm, preferably of 1.0µm or less, in particular of 0.5 µm or less, which is unidirectionally aligned with it s helical axis parallel to the substrates, e. g. glass plates, of a liquid crystal cell. In this configuration the helical axis of the chiral nematic liquid crystal is equivalent to the optical axis of a birefringent plate.

If an electrical field is applied to this configuration normal to the helical axis the optical axis is rotated in the plane of the cell, similar as the director of a ferroelectric liquid crystal rotates in a surface stabilized ferroelectric liquid crystal display. The flexoelectric effect is characterised by fast response times typically ranging from 6 µs to 100 µs. It further features excellent grey scale capability.

The electric field can be understood to essentially flexoelectrically couple to the induced splay-bend deformation of the director. The angle of the rotation of the axis is in first approximation directly and linearly proportional to the strngth of the electrical field. The optical effect is best seen when the liquid crystal cell is placed between crossed polarizers with the optical axis in the unpowered state at an angle of 22.5° to the absorption axis of one of the polarizers. This angle of 22.5° is also the ideal angle of rotation of the of the electric field, as thus, by the inversion the electrical field, the optical axis is rotated by 45° and by appropriate selection of the relative orientations of the preferred direction of the axis of the helix, the absorption axis of the polarizer and the direction of the electric field, the the optical axis can be switched from parallel to one polarizer to the center angle between both polarizers. The optimum contrast is then achieved when the total angle of the switching of the optical axis is 45°. In that case the arrangement can be used as a swtchable quarter wave plate, provided the optical retardation, i. e. the product of the effective birefringence of the liquid crystal and the cell gap, is selected to be the quarter of the wave length. In this context the wavelength referred to is 550 nm, the wavelenght for which the sensitivity of the human eye is highest, unless explicitly stated otherwise.

The angle of rotation of the optical axis (Φ) is given in good approximation by formula (1).

$$\tan \Phi = \bar{e}\ P_0 E / (2 \pi K) \qquad (1)$$

wherein

P_0 is the undisturbed pitch of the cholesteric liquid crystal,

$\bar{e}$ is the average $[\bar{e} = \frac{1}{2} (e_{splay} + e_{bend})]$ of the splay flexoelectric coefficient (e_{splay}) and the bend flexoelectric coefficient (e_{bend}),

E is the electrical field strength and

K is the average $[K = \frac{1}{2} (k_{11} + k_{33})]$ of the splay elastic constant (k_{11}) and the bend elastic constant (K_{33})

and wherein

$\bar{e} / K$ is called the flexo-elastic ratio.

This angle of rotation is half the switching angle in a frexoelectric switching element.

The response time (τ) of this electro-optical effect is given in good approximation by formula (2).

$$\tau = [P_0/(2\pi)]^2 \cdot \gamma / K \qquad (2)$$

wherein

γ is the effective viscosity coefficient associated with the distortion of the helix.

There is a critical field (E_c) to unwind the helix, which can be obtained from equation (3).

$$E_c = (\pi^2 / P_0) \cdot [k_{22}/(\varepsilon_0 \cdot \Delta\varepsilon)]^{1/2} \qquad (3)$$

wherein

k_{22} is the twist elastic constant,
ε_0 is the permittivity of vacuum and
$\Delta\varepsilon$ is the dielectric anisotropy of the liquid crystal.

Liquid Crystal Displays (LCDs) are widely used to display information. Electro-optical modes employed are e.g. the twisted nematic (TN)-, the super twisted nematic (STN)-, the optically compensated bend (OCB)- and the electrically controlled birefringence (ECB)-mode with their various modifications, as well as others. Besides these modes, which all do use an electrical field, which is substantially perpendicular to the substrates, respectively to the liquid crystal layer, there are also electro-optical modes employing an electrical field substantially parallel to the substrates, respectively the liquid crystal layer, like e.g. the In-Plane Switching mode (as disclosed e.g. in DE 40 00 451 and EP 0 588 568). Especially this electrooptical mode is used for LCDs for modern desk top monitors.

The liquid cystals according to the present invention are preferably used in flexoelectric, chiral nematic devices, preferably in displays or in electrooptical devices like switches for light or optical components.

Preferably displays according to the present invention are addressed by an active matrix i.e. a matrix of active electrical elements with a nonlinear current - voltage characteristic. These active elements preferably are thin film transistors (TFTs). They can be used for direct view applicatoins as well as for projection type displays.

A chiral substance mixted with a nematic material induces a helical twist transforming the material into a chiral nematic material, which is equivalent to a cholesteric material. The terms chiral nematic and cholesteric are used synonymously in this application, unless explicitly stated otherwise. One difference between a cholesteric material and a chiral nematic material, however, is the fact, that the cholesteric pitch of the latter can be varied over a rather large range with comparative ease. The pitch induced by the chiral substance is in a first approximation inveresely proportional to the concentration of the chiral material used. The constant of proportionality of this relation is called the helical twisting power (HTP) of the chiral substance and defined by equation (4)

$$\mathrm{HTP} \equiv 1 / (c \cdot P_0) \qquad (4)$$

wherein

c is concentration of the chiral compound.

For these displays new liquid crystalline media with improved properties are required. Especially the birefingence (Δn) should be optimised for the optical mode. I.e. the optical retardation ($d \cdot \Delta n$) should be preferably such that the equation (5)

$$\sin^2(\pi \cdot d \cdot \Delta n / \lambda) = 1 \qquad (5)$$

wherein

d is the cell gap and

λ is the wave length of light

is satisfied. The allowance of deviation for the right hand side of equation (5) is +/- 3%.

The wave length of light generally referred to in this application is 550 nm, unless explicitly specified otherwise.

The cell gap of the cells preferably is in the range from 1 μm to 20 μm, in particular with in the range from 2.0 μm to 10 μm.

Further, on the one hand, the dilectric anisotropy ($\Delta\varepsilon$) should be high enough to allow the coupling of the electrcal field during orientation of the chiral nematic liquid crystal, but,on the other hand, at the same time it should be as small as possible, to prevent unwinding of the helix upon application of the addressing voltage. Preferably $\Delta\varepsilon$ should be higher than 0 and very preferably preferably be 0.1 or more, but preferably 10 or less, more preferably 7 or less and most preferably 5 or less. Besides these parameters, the media have to exhibit a suitably wide range of the nematic phase, a rather small rotational viscosity and an at least moderately high specific resistivity.

The displays according to the present invention are preferably addressed by an active matrix (active matrix LCDs, short AMDs), preferably by a matrix of thin film transistors (TFTs). However, the inventive liquid crystals can also beneficiously be used in displays with other known addressing means.

Liquid crystal compositions with short cholesteric pitch for flexoelectric devices are known from EP 0 971 016, GB 2 356 629 and Coles, H.J., Musgrave, B., Coles, M.J., and Willmott, J., J. Mater. Chem., **11**, p. 2709-2716 (2001). EP 0 971 016 teaches (reports on) mesogenic estradiols, which, as such, have a high flexoelectrc coefficient. GB 2 356 629 teaches (reports on) bimesogenic compounds and their use in flexoelectric devices. The flexooelectric effect has been investigated in pure cholesteric liquid crystal compounds and in mixtures of homologous compounds only so far. Most of these compounds were used in binary mixtures consisting of a chiral additive and a nematic liquid crystal material beeing either a simple, conventional monomesogenic material or a bimesogenic one. These materials do have several drawbacks for practical applications, like insufficiently wide temperature ranges of the chiral nematic – or cholesteric phase, too small flexoelectric ratios, small angles of rotation.

The cyanobiphenyl-based bimesogens have low solubility and are nematic at high temperatures (e.g. the switching behaviour of CBO8OCB + 3% BDH-1281 can only be investigated above 168°C). Therefore, they are not suitable for practical applications since they cannot be used in room temperature displays (see J. Mater. Chem., **11**, p. 2709-2716 (2001)). The monomesogenic materials exhibit good solubility properties but in chiral-doped systems, the helix unwinds at low voltages (e.g. for 7CB + 4% BDH-1305, the maximum tilt angle is 6° before the helix unwinds at about 20V for a 4μm thick cell). Furthermore, the investigations on these systems were performed at relatively high relative temperatures which are only slightly below the respective clearing points of the materials, typically about 12°C below the clearing point.

Similar difficulties were encountered with the pure cholesteric materials such as the homologous series of estradiols. These are not liquid crystalline at room temperature and additionally, the maximum rotation angles achieved are only 10° or less.

Thus, there is a significant need for liquid crystalline media with suitable properties for practical applications such as e.g. computer monitors, screens for television sets and the like, displays for multi media applications, hand held tele-communication devices, automatic teller machines and light modulators. They have to have a wide nematic phase range, low viscosities, a high $\Delta\varepsilon$, a sufficiently high resistivity and, in particular, an appropriately optimised optical anisotropy Δn-for a given cell thickness depending on the display mode used.

Present invention

Surprisingly, it now has been found that liquid crystalline media with a sufficiently wide range of the chiral nematic phase and suitably high flexoelastic ratio and sufficiently short response time can be realised using a nematic base mixture in which one or more chiral compounds. The effect is even largely improved if a mixture of bimesogens is used, to which one or more chiral compounds are added. These media according to the present invention do not exhibit the drawbacks of the materials of the prior art or at least do exhibit them to a significantly lesser degree.
Preferably the base mixtures used in the media according to the present invention have a chiral nematic phase or, preferrably, a nematic phase,

The base mixtures preferably have a positive dielectric anisotropy, in order to further the alignment of the axis of the helix in the plane of the cell. However, at the same time, the dielectric anisotropy of the base mixturehas to be limited , as otherwise there would be an undesired unwinding of the helix upon application of the electrical field instead of the desired switching of the axis of the helix. The dielectric anisotropy of the base mixture preferably is in the range from 0 or more to 10 or less and especially preferably 8.0 or less and in particular from 0 or more to 6.0 or less, preferably from 0 or more, preferably 0.1 or more to 5 or less.

The clearing point of the mixtures according to the present invention typically are 60°C or more, preferably 80° or more, more preferably 85° or more and especially preferered 90° or more.

The unwinding voltage for the helical structure of the mixture is typically 30V or more, preferably 50V or more, more preferably 70V or more and especially 75V or more at room temperature for a 5µm thick cell.

In this application the terms room temperatore and ambient temperature refer to a temperature of 20°C, unless explicitly stated otherwise.

The dielectric anisotropy of the liquid crystalline mixture (as described above) preferably is in the range from 0 or more to 10 or less and especially preferably 8.0 or less and in particular from 0 or more to 6.0 or less, preferably from 0 or more, preferably 0,1 or more to 5 or less.

The clearing point of the mixtures according to the present invention typically are 60°C or more, preferably 70° or more, more preferably 75° or more and especially preferered 80° or more.

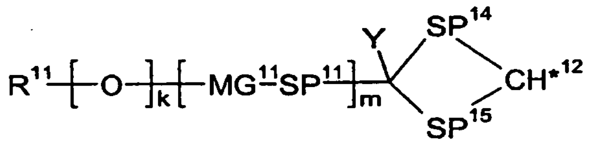
The unwinding voltage for the helical structure of the mixture is typically 30V or more, preferably 50V or more, more preferably 70V or more and especially 75V or more at room temperature for a 5µm thick cell.

The tilt angle for the liquid crystalline mixture is typically 5° or more, preferably 10° or more, more preferably 15° or more, and especially 22.5° for a voltage of typically 10V or more, for 5µm cell thickness, at room temperature.

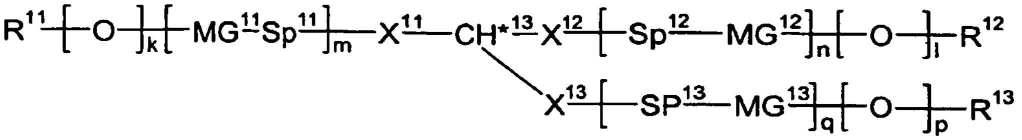
These improved liquid crystalline media according to the instant application are comprising at least two, preferably at least three of the following components:

- a chiral component, component A, which is preferably a mesogenic component, preferrably consisting of chiral compounds, preferably comprising one or more compounds selected from the group of formulae I, I' and I"

$$R^{11}-\left[O\right]_k-\left[MG^{11}-Sp^{11}\right]_m-X^{11}-CH^{*11}-X^{12}-\left[Sp^{12}-MG^{12}\right]_n-\left[O\right]_l-R^{12} \qquad \mathrm{I}$$



I'



$$R^{11}\left[O\right]_k\left[MG^{11}-Sp^{11}\right]_m-X^{11}-CH^{*}\overset{13}{-}X^{12}\left[Sp^{12}-MG^{12}\right]_n\left[O\right]_l-R^{12}\qquad \text{I''}$$
$$\diagdown X^{13}\left[SP^{13}-MG^{13}\right]_q\left[O\right]_p-R^{13}$$

wherein

R^{11} R^{12} and R^{13} are each, independently of one another, H, F, Cl, CN, NO_2, NCS, SCN, OCN, a stright chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH_2 groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, $-N(CH_3)-$, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH, -CF=CF- or $-C\equiv C-$ in such a manner, that oxygen atoms are not linked directly to one another or, in case they are not linked to an O atom, H,

SP^{11}, SP^{12} and SP^{13} are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms, preferably an alkylen group, it beeing also possible for one or more groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, $-N(CH_3)-$, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, $-CF_2-$ or $-C\equiv C-$ in such a manner, that oxygen atoms are not linked directly to one another,

SP^{14} and SP^{15} are each, independently of one another, a single bond or a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms, preferably an alkylen group, it beeing also possible for one or more groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -

$N(CH_3)$-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, $-CF_2-$ or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another, preferably SP^{14} and SP^{15} are identical to each other, most preferably an an alkylen group with 1 to 4 C atoms and in particular with 1 or 2 C atoms,

X^{11}, X^{12} and X^{13} are each, independently of one another, -O-, -S-, -CO-, -COO-, -OCO-, -OCOO-, -CO-NH-, -NH-CO-, $-CH_2CH_2-$, $-OCH_2-$, $-CH_2O-$, $-SCH_2-$, $-CH_2S-$, -CF=CF-, -CH=CH-, -COO-, -OCO-CH=CH-, -C≡C- or a single bond,

Y has the meaning given for R^{11} and is preferably H, F, CH_3 or CF_3, more preferably H or F,

k, l, n, m, p and q each are 0 or 1,

m is preferably 1,

m+n+q is 1, 2 or 3, for formula I preferably 2, for formula I' preferably 1 and for formula I" preferably 2 or 3 and most preferably 2,

MG^{11}, MG^{12} and MG^{13} are each, independently of one another, a mesogenic group, preferably of the formula I'"

$$-A^{11}-(Z^{1}-A^{12})_{i1}- \qquad I'''$$

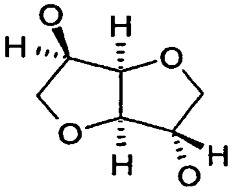
wherein

A^{11} and A^{12} are each, independently of one another, a bivalent ring group containing preferably at least four C atoms, preferably a five- or a six-membered ring and prferably has the meaning given for ring A^{31} under formula III below,

Z^1 each have , independently of one another, the meaning given for Z^{31} under formula III below and

i1 is 0, 1 or 2, preferably 0 or 1,

CH^{*11} is a chiral, bivalent group, preferably with a chiral center or with one or more chiral atoms preferably selected from the group of formulae Ia to In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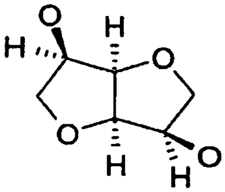
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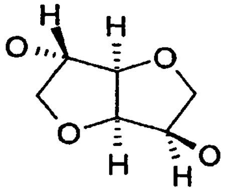
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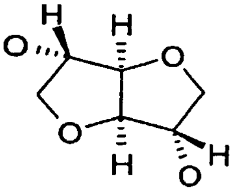
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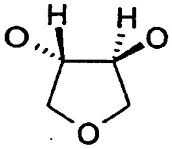
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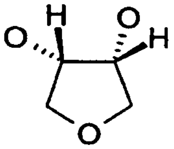
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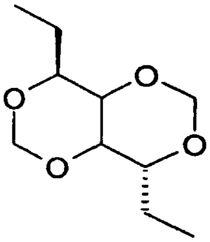
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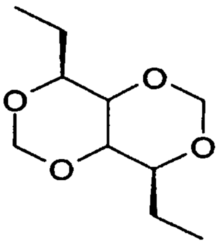
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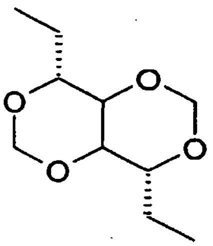
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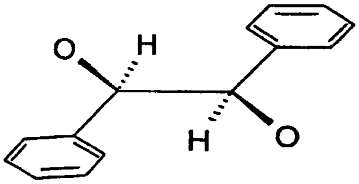
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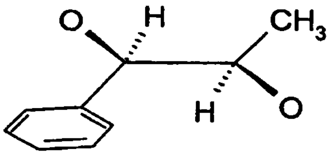
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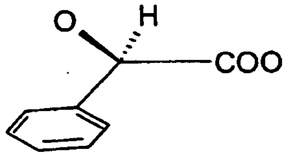

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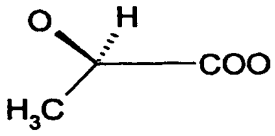

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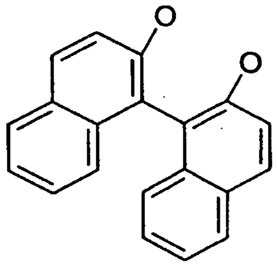


In , or their mirror images, if not depicted,

CH*^{12} is a chiral, bivalent group, preferably with a chiral center or with one or more chiral atoms preferably selected from the group of formulae Ie, If and In, or their mirror images, if not depicted, especially preferred In, and

CH*^{13} is a chiral, trivalent group, preferably with a chiral center or with one or more chiral atoms preferably -CH=, -CF=, -C(CH$_3$)=, -C(OCH$_3$)= or –C(CF$_3$)=

where in all groups Ia to Ik, and especially preferred in the aromatic rings of groups Ij, Ik, I l and In, optionally one or more hydrogen atoms can be replaced by further aromatic rings, aliphatic rings, alkyl chains, alkoxy chains, alkenyl chains and alkenyloxy chains, which all may be substituted by fluorine halogen atoms or CN,

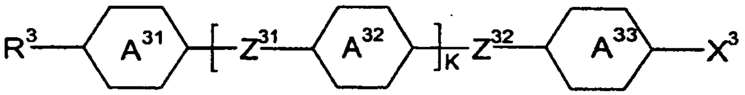
- a bimesogenic component, component B, which is preferably a mesogenic component preferrably consisting of bimesogenic compounds, preferably comprising one or more compounds of formula II,

$$R^{21}-\left[-O-\right]_i-MG^{21}-SP^2-MG^{22}-\left[-O-\right]_j-R^{22}$$ I

wherein

R^{21} and R^{22}	, independently of each other, have the meaning given for R^{11} under formula I above,
MG^{21} and MG^{22}	, independently of each other, have the meaning given for MG^{11} under formula I above,
SP^2	has the meaning given for SP^{11} under formula I above and,
i and j	are, independently of each other, 0 or 1,

- a dielectrically positive component, component C, consisting of dielectrically positive compounds, preferably comprising one or more compounds of formula III and, optionally, further dielectrically positive compounds



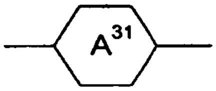
III

wherein

R^3	is H, F, alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms,

X^3 H, CN, NCS, F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably CN, OCF_3, OCF_2H, F or Cl, most preferably OCF_3 or H,

Z^{31} and Z^{32}, independently of each other, and incase Z^{31} is present twice, also these independently of each other, are $-CH_2-CH_2-$, $-CF_2-CF_2-$, $-CF_2-O-$, $-O-CF_2-$ -CO-O- or a single bond, preferably $-CH_2-CH_2-$, -CO-O- or a single bond,



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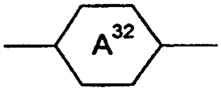

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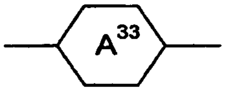

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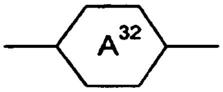

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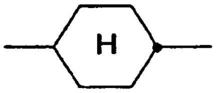

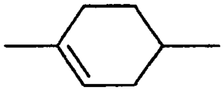

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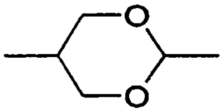

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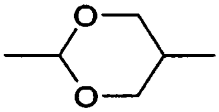

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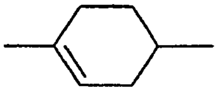

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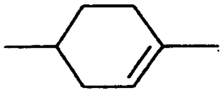

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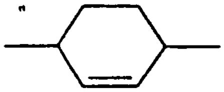

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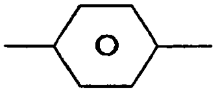

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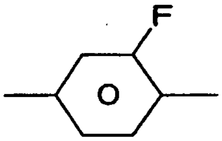

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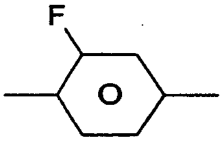

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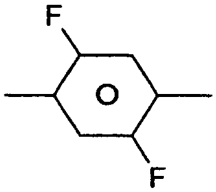

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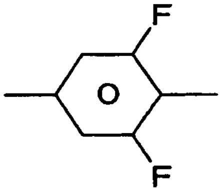

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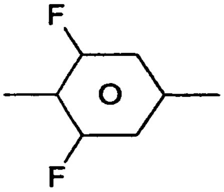

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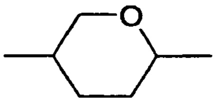

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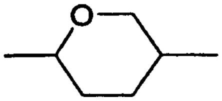

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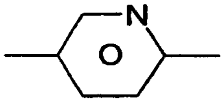

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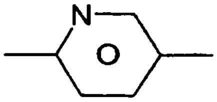

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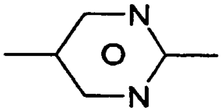

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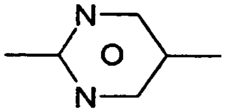

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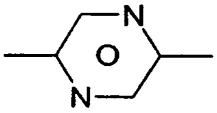
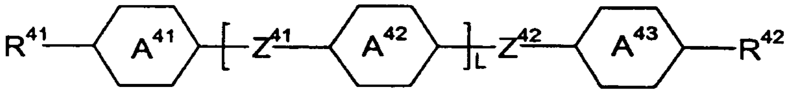


,

K is 0, 1 or 2, preferably 0 or 1,

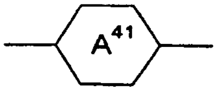
- optionally, preferably obligatorily, a dielectrically negative component, component D, consisting of dielectrically negative compounds, preferably comprising one or more compounds of formula IV



IV

wherein

R^{41} and R^{42} independently of each other have the meaning given for R^3 under formula III above,



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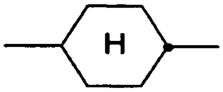

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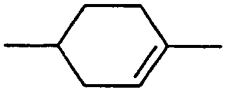
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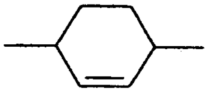

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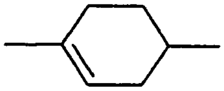
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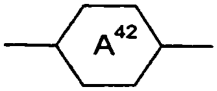

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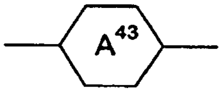

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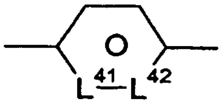
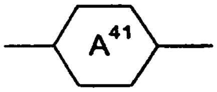


and the other one has, ort the other two, independently of each other, have the same meaning, or one of the meenings given for



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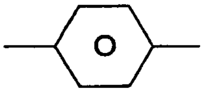

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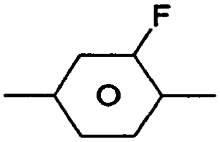

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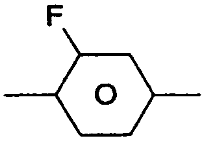
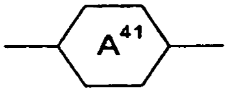


optionally one of



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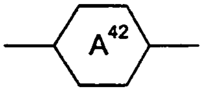

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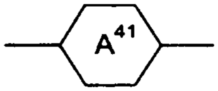
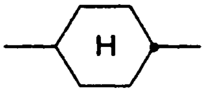


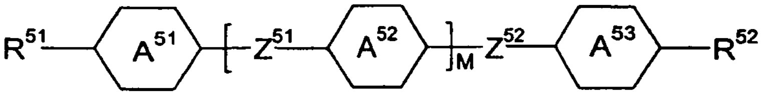
is, or both are



,

L^{41} and L^{42}	are, independently of each other, =C(-F)- or =N-, preferably at least one of them is =C(-F)- and, most preferably, both of them are =C(-F)- and
Z^{41} and Z^{42}	are, independently of each other, -CH_2CH_2-, -COO-, trans- CH=CH-, trans- -CF=CF-, -CH_2O-, -CF_2O- or a single bond, preferably at least one of them is a single bond and most preferably both are a single bond,
L	is 0 or 1 or 2, preferably 0 or 1.

- optionally, preferably obligatorily, a dielectrically neutral component, component E, consisting of dielectrically neutral compounds, preferably comprising one oe more compounds of formula V



V

wherein

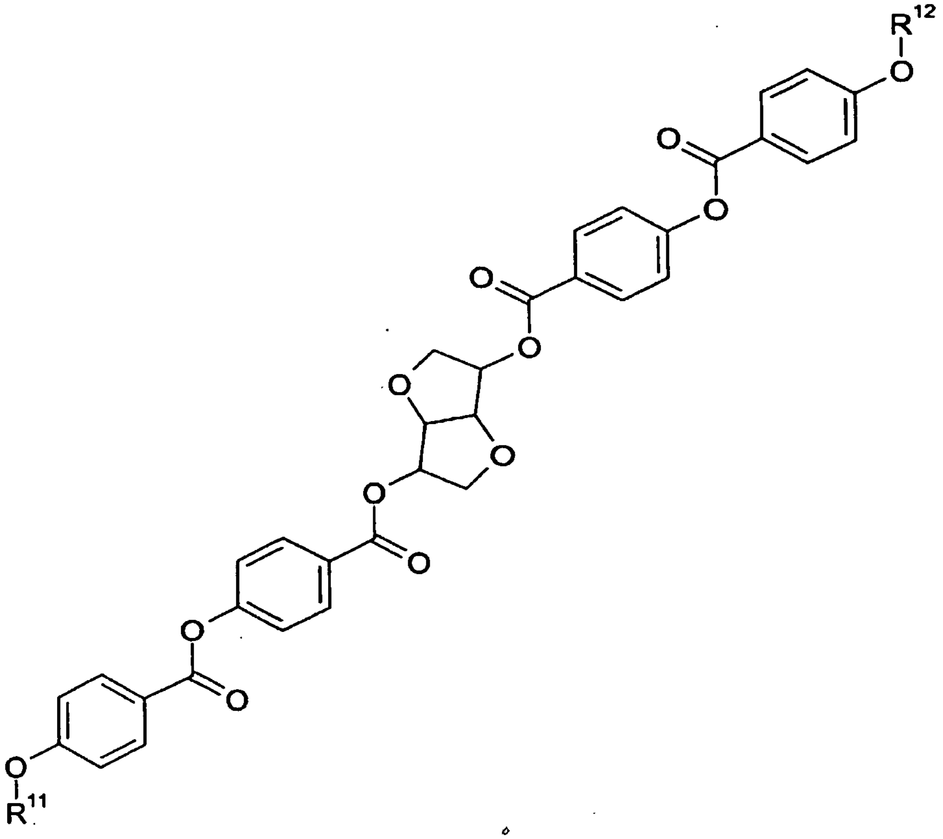
R^{51} and R^{52} , independently of each other, have the meaning given for R^3 under formula III above,

the rings A^{51}, A^{52} and A^{53} , independently of each other, have the meaning given for ring A^{31} under formula III above,

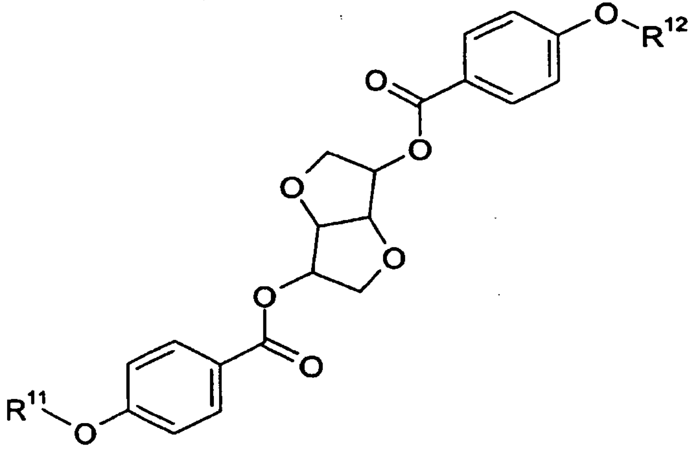
Z^{51} and Z^{52} , independently of each other, have the meaning given for Z^{31} under formula III above,

M is 0 or 1 or 2, preferably 0 or 1.

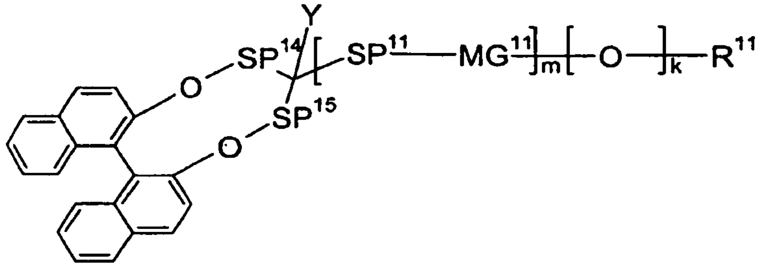
Preferably the chiral component, component A comprises one or more compounds selected from the group of formulae Ia, Ib and I'-1, preferably of it's sub-formulae I'a to I'c, preferably one ore more compounds each of at least two different formulae selected from this group of formulae



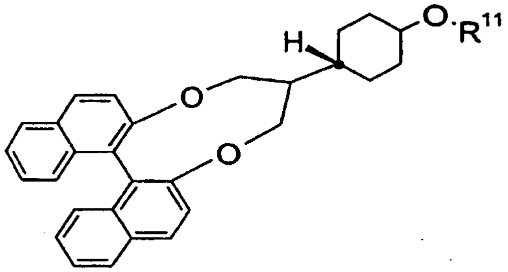
Ia



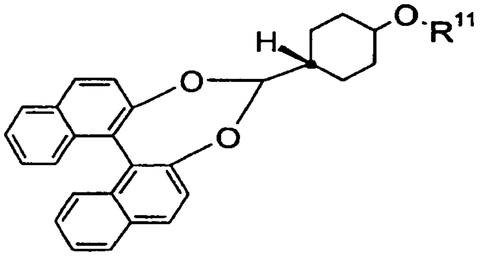
Ib



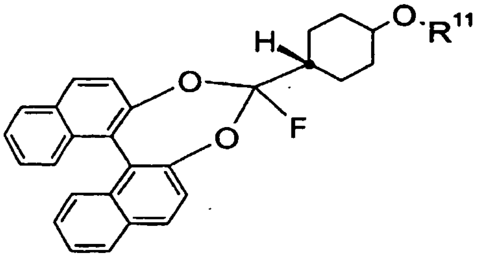
I'-1



I'a



I'b



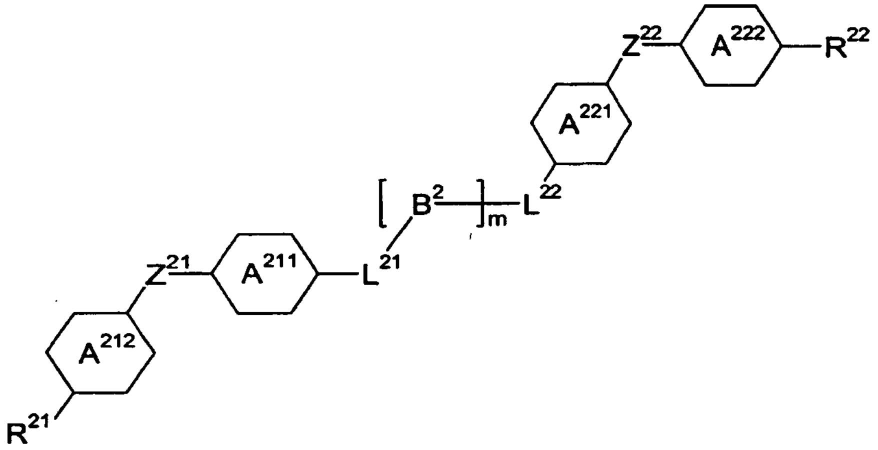
I'c

wherein the parameters have the respective meanings given under formula I above and preferably

R^{11} and R^{12}	are, independently of each other, alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-

atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms.

Preferably the bimesogenic component, component B comprises one or more compounds of formula IIa, preferably one ore more compounds each of at least two different formulae selected from this group of formulae

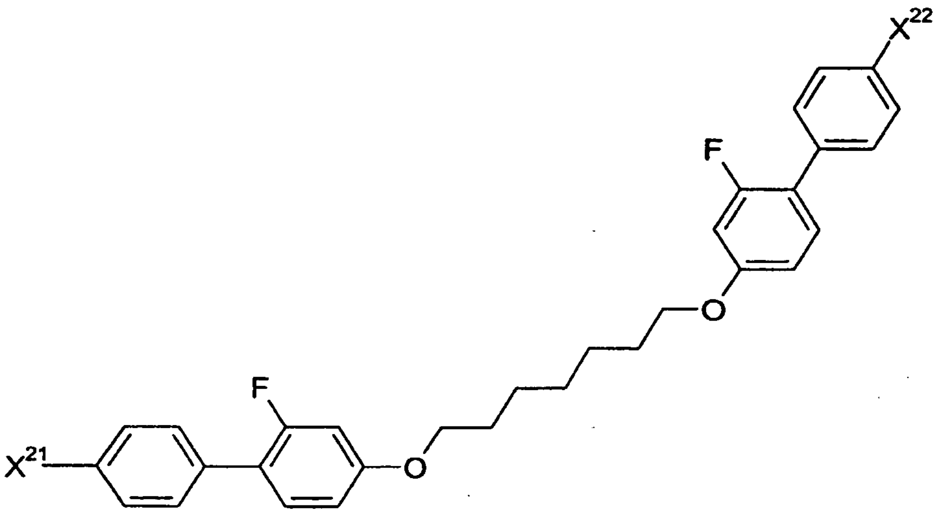


IIa

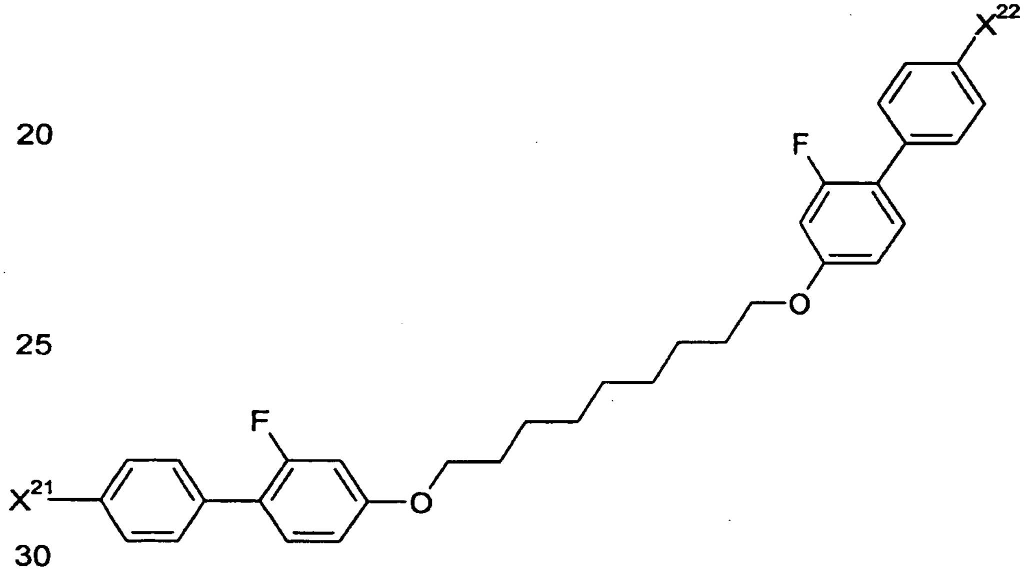
wherin

R^{21} and R^{22}	, independently of each other have the meaning given under formula II above,
the rings A^{211}, A^{212}, A^{221} and A^{222}	, independently of each other have the meaning given for ring A^{31} under formula III above,
Z^{21} and Z^{22}	, independently of each other have the meaning given for Z^{31} under formula III above,
B^2	is CH_2, CFH, CF_2 or if present more than once any combination thereof, preferably CH_2 and
m	is an integer from 1 to 19, preferably from 4 to 15 and most preferably from 6 to10.

Especially preferred are compounds of formulae IIa-1 and IIa-2



IIa-1

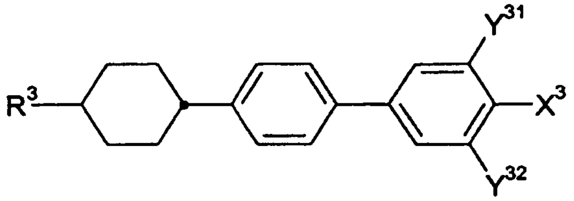


IIa-2

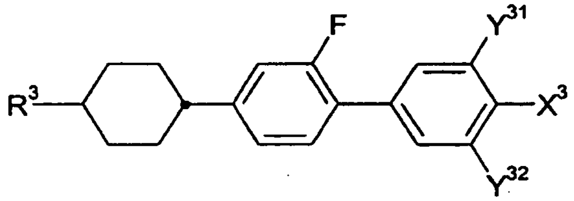
wherein

X^{21} and X^{22} have the respective meaning given for R^{11} and R^{12} under formula I above, preferably under formula Ia above or are, independently of each other, F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably F or Cl, most preferably F.

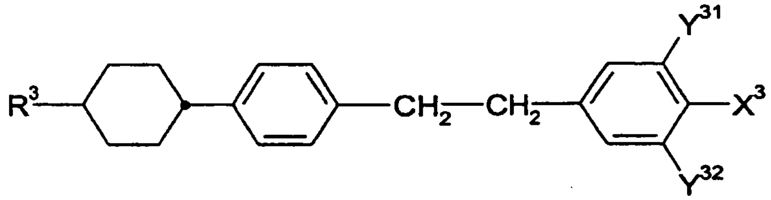
Preferably the dielectrically positive component, component C comprises one or more compounds selected from the group of formulae IIIa to IIIg, preferably one ore more compounds each of at least two different formulae selected from this group of formulae



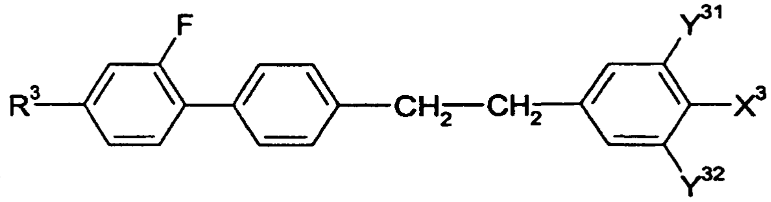
IIIa



IIIb



IIIc



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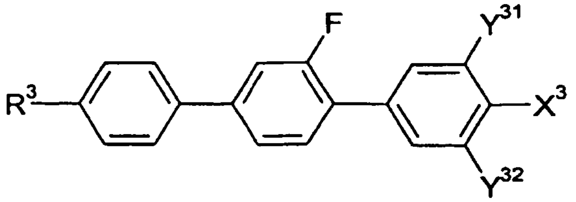
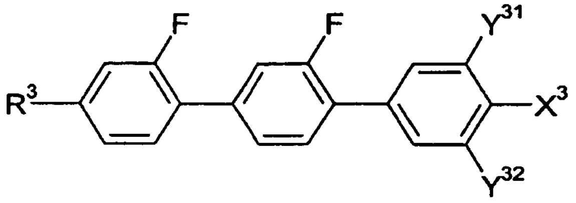
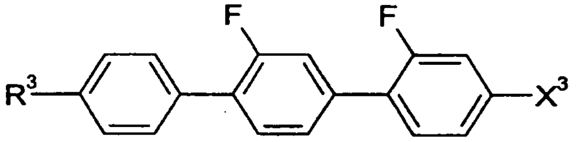


IIIe



IIIf



IIIg

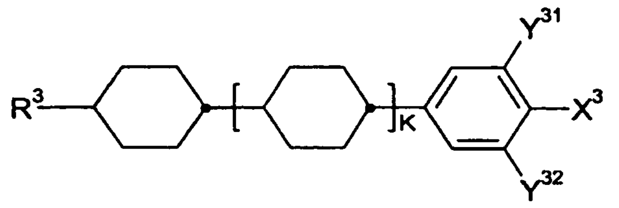
wherein

R^3	is alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms,
X^3	is F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably OCF_3, OCF_2H, F or Cl, most preferably F and
Y^{31} and Y^{32}	are, independently of each other H or F

wherein, optionally, two of the 6-membered rings shown directly linked, may be linked by a group selected from

$-CH_2-CH_2-$, $-CF_2-CF_2-$, $-CF_2-O-$, $-O-CF_2-$ and $-CO-O-$, preferably $-CH_2-CH_2-$ and $-CF_2-O-$, most preferably $-CH_2-CH_2-$.

Further, the dielectrically positive component, component C optionally comprises one or more compounds of formula IIIh



IIIh

wherein

R³ is alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms,

X³ is F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably OCF_3, OCF_2H, F or Cl, most preferably F,

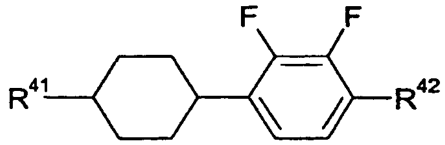
Y^{31} and Y^{32} are, independently of each other H or F and

K is 0, 1 or 2, preferably 0 or 1 and most preferably 1,

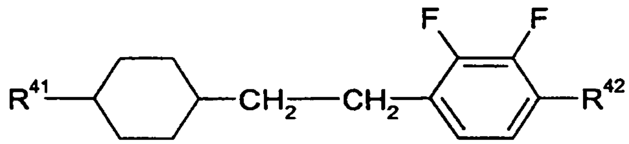
wherein, optionally, two of the 6-membered rings may be linked by a group selected from

$-CH_2-CH_2-$, $-CF_2-CF_2-$, $-CF_2-O-$, $-O-CF_2-$ and -CO-O-, preferably $-CH_2-CH_2-$ and $-CF_2-O-$, most preferably $-CH_2-CH_2-$.

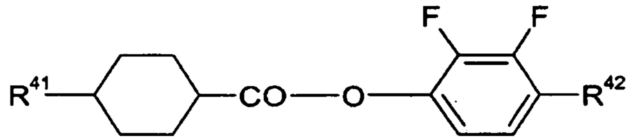
The liqiud crystral mixtures according to the present invention preferably comprise a dilectrically negative component, component D. This component has a dielectrical anisotropy of –1.5 or less, preferably in the range from –1.5 to –8. Preferably it contains essentialy and especially preferably consists entirely of dielectrically negative compounds. Preferably this component comprises one ore more dielectrically negative compounds selected from the group of of formulae IVa to IVh



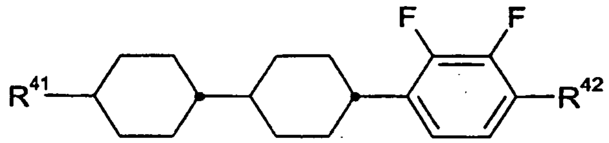
IVa



IVb



IVc



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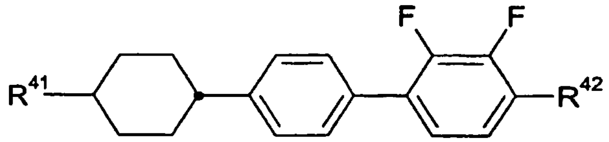

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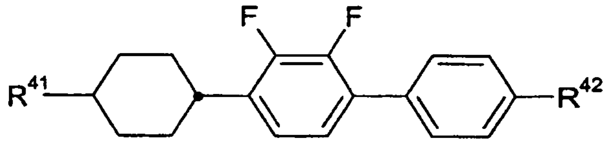

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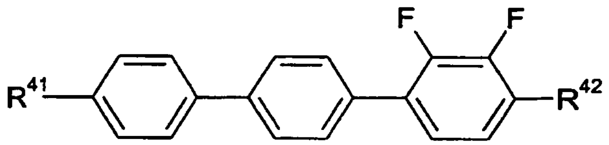

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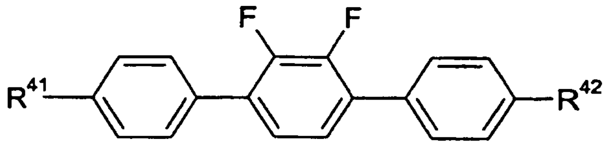
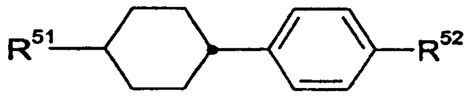


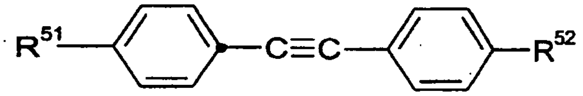
IVh

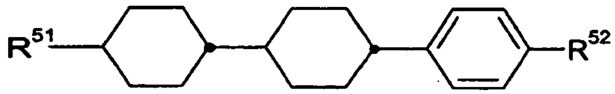
wherein

R^{41} and R^{42}	have the respective meaning given under formula IV above.

The liqiud crystral mixtures according to the present invention preferably comprise a dilectrically neutral component, component E. This component has a dielectrical anisotropy in the range from –1.5 to +3.0. Preferably it contains essentialy and especially preferably consists entirely of dielectrically neutral compounds. Preferably this component comprises one ore more dielectrically neutral compounds selected from the group of of formulae Va to Vm


V a


V b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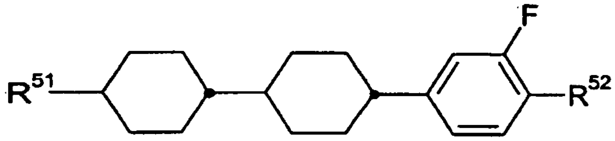
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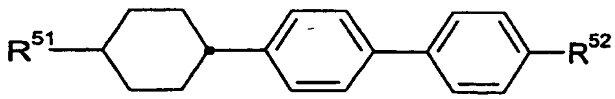
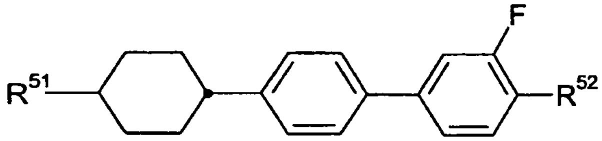

V e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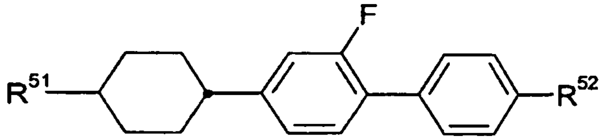
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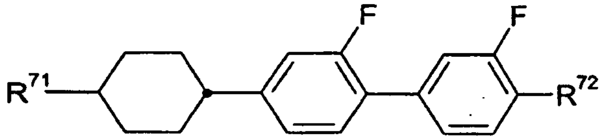
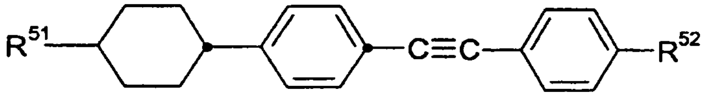

V h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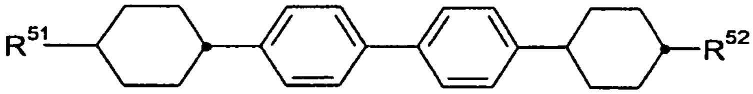
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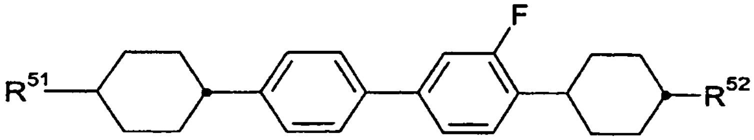
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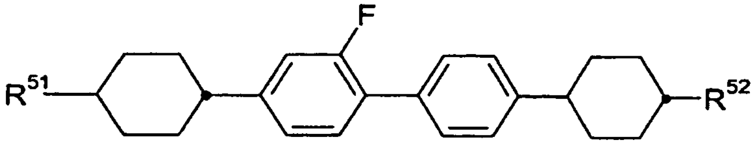
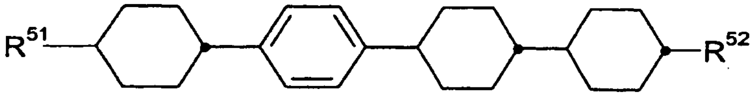

V l


V m

wherein

R^{51} and R^{52} have the respective meaning given under formula V above.

1st embodiment

The improved liquid crystalline media according to the first preferred embodiment of the instant invention comprise a chiral component (component A), a bimesogenic component (component B), a dielectric positive component(component C), and a dielectric negative component (component D). In this embodiment the components A, C and D and the optional component E can be regarded as representing the host mixture for the bimesogenic component (component B).

2nd embodiment

In a second embodiment of the instant invention, which may be identical to the first embodiment or different from that, an improvement is achieved with respect to the angles of rotation and the flexoelectric properties for flexoelectric devices at ambient temperature. In this embodiment the liquid crystalline media comprise a chiral compound (component A), bimesogens (component B), positive dielectric anisotropy compounds (component C), optionally, preferably obligatorily, neutral conpounds (component E) and optionally negative dielectric anisotropy compounds (component D).

3rd embodiment

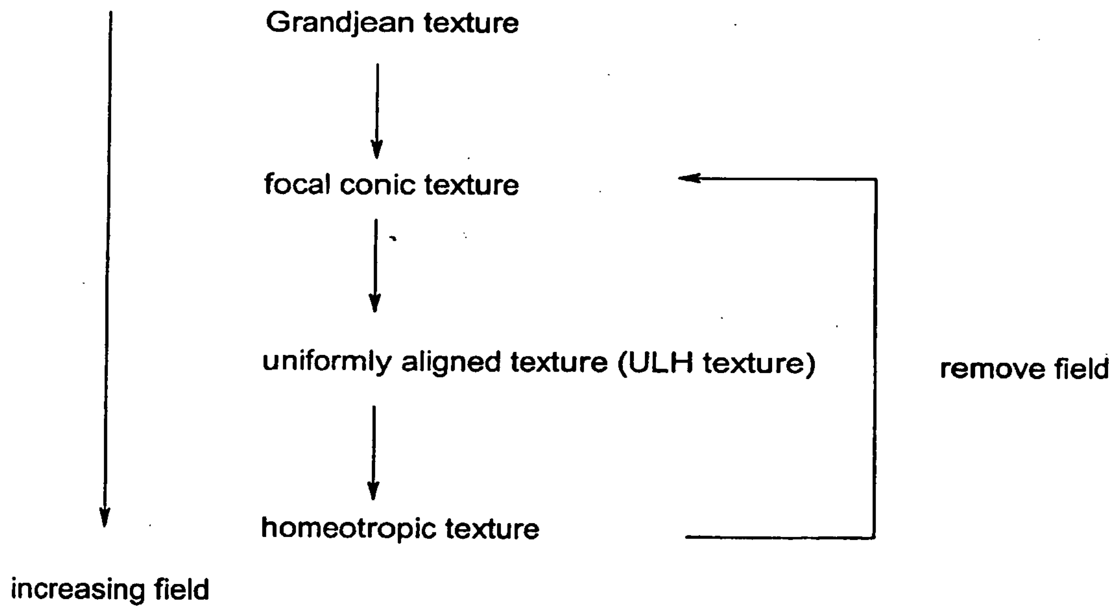
The third embodiment of the instant invention, which is independent from the two previous embodiments, but synergistically supplements them, resides in the chiral additive used. The chiral structure in liquid crystalline nematics for flexoelectric devices is achieved by adding chiral dopants. Significant improvement was obtained when binaphthol based compounds were used to replace isosorbides in terms of solubility and operating temperature range. To achieve a pitch suitable for flexoelectric devices, the chiral dopant concentration is preferably 0.5% or more, more preferably 1% or more, most preferably 1.5% or more and especially 2% or more.

Additional improvement is obtained in low temperature stability when binnaphthol dopants, preferably of formula I'a, are used compared to isosorbide dopants. Preferably the compounds of formula I' are selected from the group of formulae I'a, I'b and I'c.

The chiral nematic phase extends to preferably less than 20°C or lesss, more preferably 15°C or less, most preferably 10°C or less, especially 5°C or less.

The sequence of textures typically observed in a sample of an inventive medium upon application of an electric field is as follows:

Scheeme 1: Phase sequence during orientation



The liquid crystal base mixture preferably has an elastic constant k_{11} of $1 \cdot 10^{-11}$ N or more and the flexoelectric mixture has an average flexoelectric coefficient $\bar{e}$ of $1 \cdot 10^{-11}$ C/m or less, preferably in the range from $1 \cdot 10^{-12}$ C/m to $1 \cdot 10^{-11}$ C/m.

Preferably the liquid crystalline media according to the instant invention contain a component A comprising, preferably predominantly consisting of and most preferably entirely consisting of compounds selected from the group of of formulae I to V.

Comprising in this application means in the context of compositions that the entity referred to, e.g. the medium or the component, contains the component or components or of the compound or compounds in question, preferably in a total concentration of 10 % or more and most preferably of 20 % or more.

Predominantly consisting, in this context, means that the entity referred to contains 80 % or more, preferably 90 % or more and most preferably 95 % or more of the component or components or of the compound or compounds in question.

Entirely consisting, in this context, means that the entity referred to contains 98 % or more, preferably 99 % or more and most preferably 100.0 % of the component or components or of the compound or compounds in question.

In a preferred embodiment the liquid crystalline media according to the instant invention contains a component A comprising, preferably predominantly consisting of and most preferably entirely consisting of compounds selected from the group of formulae I, I' and I".

In a further preferred embodiment the liquid crystal medium contains a liquid crystal component B, which is preferably predominantly consisting of and most preferably entirely consisting of compounds of formula II, preferably IIa.

In a further preferred embodiment, which may be identical to the previous preferred embodiment or different from it, the liquid crystal medium contains a liquid crystal component E, which is preferably predominantly consisting of and most preferably entirely consisting of compounds of formula V.

This component E may be present, and preferably is present, besides components C and D.

Also other mesogenic, as well as nonmesogenic, compounds, which are not explicitly mentioned above, can optionally and beneficiously be used in the media according to the instant invention. Such compounds are known to the expert in the field.

Component A preferably is used in a concentration from 0 % to 10 %, preferably from 0.5 % to 8 %, more preferably from 0.5 % to 6 % and most preferably from 0.5 % to 4 %, preferably up to to 3 % of the total mixture.

Component B preferably is used in a concentration from 0 % to 97 %, preferably from 1 % to 80 %, more preferably from 10 % to 70 % and most preferably from 10 % to 60 % of the total mixture.

Component C preferably is used in a concentration from 0 % to 97 %, preferably from 1 % to 80 %, more preferably from 1 % to 50 % and most preferably from 5 % to 50 % of the total mixture.

Component D preferably is used in a concentration from 0 % to 97 %, preferably from 0 % to 90 %, more preferably from 0 % to 70 % and most preferably from 0 % to 60 % of the total mixture.

Component E preferably is used in a concentration from 0 % to 97 %, preferably from 1 % to 80 %, more preferably from 1% to 50 % and most preferably from 5 % to 30 % of the total mixture.

Optionally, the inventive media can comprise further liquid crystal compounds in order to adjust the physical properties. Such compounds are known to the expert. Their concentration in the media according to the instant invention is preferably 0 % to 30 %, more preferably 0 % to 20 % and most preferably 0.5 % to15 %.

Preferably the liquid crystal medium contains 50 % to 100 %, more preferably 70 % to 100 % and most preferably 80 % to 100 % and in particular 90 % to 100 % totally of components A, B, C, D and E, which contain, preferably predominantly consist of and most preferably entirely consist of one or more of compounds of formulae I to V, respectively.

The liquid crystal media according to the instant invention are characterized by a clearing point of 70 °C or more, preferably of 80 °C or more and in particular of 87 °C or more.

The Δn of the liquid crystal media according to the instant invention is 0.050 or more, preferably in the range of 0.060 to 0.200, more preferably in the range of 0.060 to 0.170, most preferably in the range of 0.080 to 0.150 and in particular in the range of 0.080 to 0.138.

The $\Delta\varepsilon$, at 1 kHz and 20 °C, of the liquid crystal media according to the invention is 0 or more, preferably 0.1 or more, most preferably 0.5 or more and in particular 0.6 or more. It is, however, preferably 7.0 or less, more preferably 5.0 or less and most preferably 4.0 or less.

Preferably the nematic phase of the inventive media extends at least from 0 °C to 70 °C, more preferably at least from -20 °C to 80 °C, more preferably at least from -20 °C to 90 °C, most preferably at least from -30 °C to 90 °C and in particular at least from –30 °C to 100 °C, wherein at least means that preferably the lower limit is under cut, wherein the upper limit is surpassed.

In the present application the term dielectrically positive compounds describes compounds with $\Delta\varepsilon > 3.0$, dielectrically neutral compounds are compounds with $-1.5 \leq \Delta\varepsilon \leq 3.0$ and dielectrically negative compounds are compounds with $\Delta\varepsilon < -1.5$. The same holds for components. $\Delta\varepsilon$ is determined at 1 kHz and 20 °C. The dielectrical anisotropies of the compounds is determined from the results of a solution of 10 % of the individual compounds in a nematic host mixture. The capacities of these test mixtures are determined both in a cell with homeotropic and with homogeneous alignment. The cell gap of both types of cells is approximately 10 µm. The voltage applied is a rectangular wave with a frequency of 1 kHz and a root mean square value typically of 0.5 V to 1.0 V, however, it is always selected to be below the capacitive threshold of the respective test mixture.

For dielectrically positive compounds the mixture ZLI-4792 and for dielectrically neutral, as well as for dielectrically negative compounds, the mixture ZLI-3086, both of Merck KGaA, Germany are used as host mixture, respectively. The dielectric permittivities of the compounds are determined from the change of the respective values of the host mixture upon addition of the compounds of interest and are extrapolated to a concentration of the compounds of interest of 100 %. Components having a nematic phase at the measurement temperature of 20 °C are measured as such, all others are treated like compounds.

The term threshold voltage refers in the instant application to the optical threshold and is given for 10 % relative contrast (V_{10}) and the term saturation voltage refers to the optical saturation and is given for 90 % relative contrast (V_{90}) both, if not explicitly stated otherwise. The capacitive threshold voltage (V_0, also called Freedericksz-threshold V_{Fr}) is only used if explicitly mentioned.

The ranges of parameters given in this application are all including the limiting values, unless explicitly stated otherwise.

Throughout this application, unless explicitly stated otherwise, all concentrations are given in mass percent and relate to the respective complete mixture, all temperatures are given in degrees centigrade (Celsius) and all differences of temperatures in degrees centigrade. All physical properties have been and are determined according to "Merck Liquid Crystals, Physical Properties of Liquid Crystals", Status Nov. 1997, Merck KGaA, Germany and are given for a temperature of 20 °C, unless explicitly stated otherwise. The optical anisotropy (Δn) is determined at a wavelength of 589.3 nm. The dielectric anisotropy ($\Delta\varepsilon$) is determined at a frequency of 1 kHz. The threshold voltages, as well as all other electro-optical properties have been determined with test cells prepared at Merck

KGaA, Germany. The test cells for the determination of $\Delta\varepsilon$ had a cell gap of 22 µm. The electrode was a circular ITO electrode with an area of 1.13 cm^2 and a guard ring. The orientation layers were lecithin for homeotropic orientation ($\varepsilon_{||}$) and polyimide AL-1054 from Japan Synthetic Rubber for homogeneuous orientation ($\varepsilon_{\perp}$). The capacities were determined with a frequency response analyser Solatron 1260 using a sine wave with a voltage of 0.3 V_{rms}. The light used in the electro-optical measurements was white light. The experimental set up used, consisted of a polarising Olympus microscope equipped with a fast photodiode, whose output signal was monitored on an oscilloscope. External electric fields were applied.

The liquid crystal media according to the present invention can contain further additives and chiral dopants in usual concentrations. The total concentration of these further constituents is in the range of 0 % to 10 %, preferably 0.1 % to 6 %, based on the total mixture. The concentrations of the individual compounds used each are preferably in the range of 0.1 % to 3 %. The concentration of these and of similar additives is not taken into consideration for the values and ranges of the concentrations of the liquid crystal components and compounds of the liquid crystal media in this application.

The inventive liquid crystal media according to the present invention consist of several compounds, preferably of 3 to 30, more preferably of 8 to 20 and most preferably of 10 to 16 compounds.

These compounds are mixed in conventional way. As a rule, the required amount of the compound used in the smaller amount is dissolved in the compound used in the greater amount. In case the temperature is above the clearing point of the compound used in the higher concentration, it is particularly easy to observe completion of the process of dissolution. It is, however, also possible to prepare the media by other conventional ways, e. g. using so called pre-mixtures, which can be e. g. homologous or eutectic mixtures of compounds or using so called multi-bottle-systems, the constituents of which are ready to use mixtures themselves.

By addition of suitable additives, the liquid crystal media according to the instant invention can be modified in such a way, that they are usable in all known types of liquid crystal displays, either using the liquid crystal media as such, like TN-, TN-AMD, ECB-AMD, VAN-AMD, IPS and OCB LCDs and in particular in composite systems, like PDLC, NCAP, PN LCDs and especially in projectoin type TFT displays.

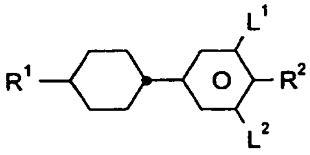
The orientation of the liquid crystal media according to the present invention in the inventive cells is typically achieved by treating the major inner surfaces of the cell opposing each other with an aligning means for homogeneous alignment and application of an electrical field to the foilled cell. The means for homeotropic orientation is an inorganic layer with a preferred direction, like e.g. obliquely evaporated SiO_x or an organic layer, typically a polymeric layer, having a preferred direction, like an uniderectionally rubbed polyimide or polyamide film.

The melting point T(C,N), the transition from the smectic (S) to the nematic (N) phase T(S,N) and the clearing point T_c(N,I) of the liquid crystals are given in degrees centigrade.

In the present application and especially in the following examples, the structures of the liquid crystal compounds are represented by abbreviations also called acronyms. The transformation of the abbreviations into the corresponding structures is straight forward according to the following two tables A and B. All groups C_nH_{2n+1} and C_mH_{2m+1} are straight chain alkyl groups with n respectively m C-atoms. The interpretation of table B is self evident. Table A does only list the abbreviations for the cores of the structures. The individual compounds are denoted by the abbreviation of the core followed by a hyphen and a code specifying the substituents R^1, R^2, L^1 and L^2 as follows:

Code for R^1, R^2, L^1, L^2	R^1	R^2	L^1	L^2
nm	C_nH_{2n+1}	C_mH_{2m+1}	H	H
nOm	C_nH_{2n+1}	OC_mH_{2m+1}	H	H
nO.m	OC_nH_{2n+1}	C_mH_{2m+1}	H	H
n	C_nH_{2n+1}	CN	H	H
nN.F	C_nH_{2n+1}	CN	F	H
nN.F.F	C_nH_{2n+1}	CN	F	F
nF	C_nH_{2n+1}	F	H	H
nF.F	C_nH_{2n+1}	F	F	H
nF.F.F	C_nH_{2n+1}	F	F	F
nOF	OC_nH_{2n+1}	F	H	H
nCl	C_nH_{2n+1}	Cl	H	H
nCl.F	C_nH_{2n+1}	Cl	F	H
nCl.F.F	C_nH_{2n+1}	Cl	F	F
nCF_3	C_nH_{2n+1}	CF_3	H	H
nCF_3.F	C_nH_{2n+1}	CF_3	F	H
nCF_3.F.F	C_nH_{2n+1}	CF_3	F	F
$nOCF_3$	C_nH_{2n+1}	OCF_3	H	H
$nOCF_3$.F	C_nH_{2n+1}	OCF_3	F	H
$nOCF_3$.F.F	C_nH_{2n+1}	OCF_3	F	F
$nOCF_2$	C_nH_{2n+1}	$OCHF_2$	H	H
$nOCF_2$.F	C_nH_{2n+1}	$OCHF_2$	F	H
$nOCF_2$.F.F	C_nH_{2n+1}	$OCHF_2$	F	F
nS	C_nH_{2n+1}	NCS	H	H
nS.F	C_nH_{2n+1}	NCS	F	H
nS.F.F	C_nH_{2n+1}	NCS	F	F
rVsN	C_rH_{2r+1}-CH=CH-C_sH_{2s}-	CN	H	H
rEsN	C_rH_{2r+1}-O-C_sH_{2s}-	CN	H	H
nAm	C_nH_{2n+1}	$COOC_mH_{2m+1}$	H	H

Table A:



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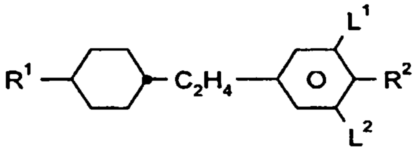

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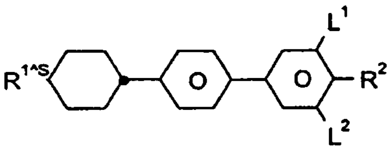

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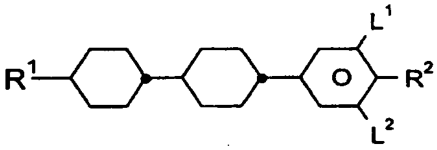

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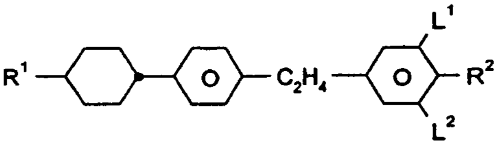

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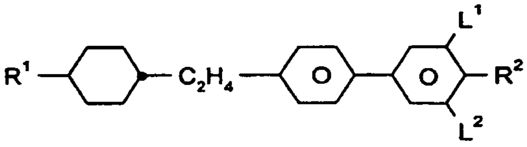

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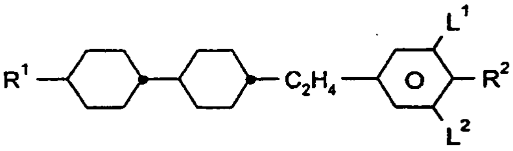
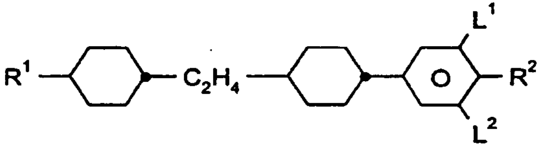


ECCP



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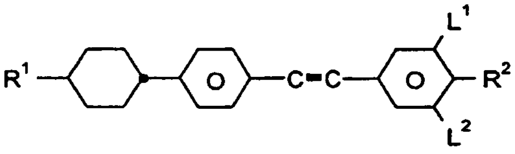
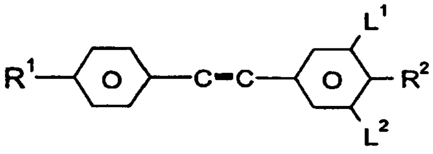


CPTP



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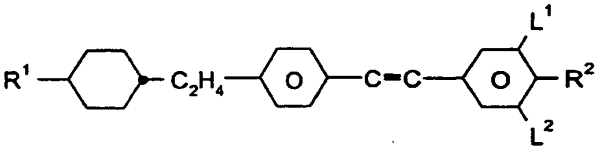

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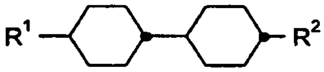

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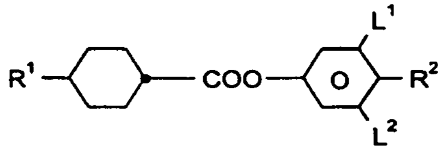

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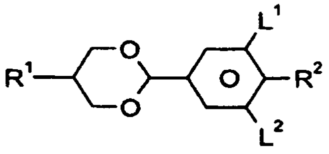

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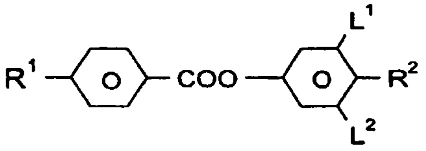

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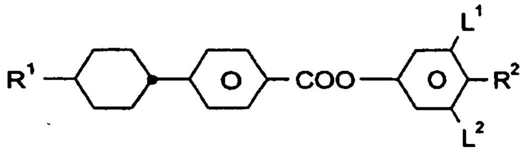

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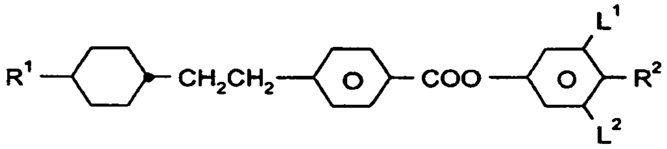
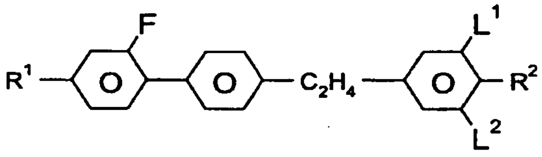
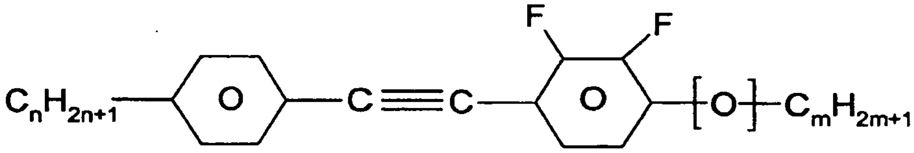


EHP

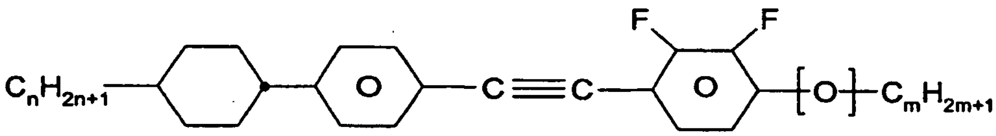


FET

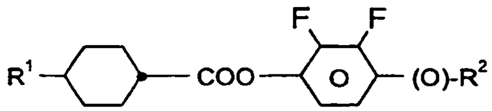
Table B:



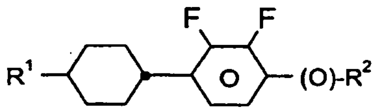
PTP-n(O)mFF



CPTP-n(O)mFF



D-n(O)mFF



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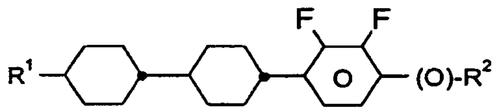
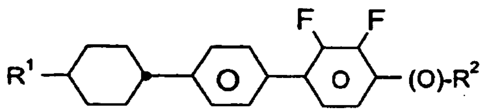
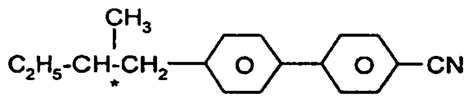


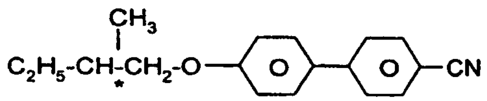
CCP-n(O)mFF



BCH-n(O)mFF



CB15



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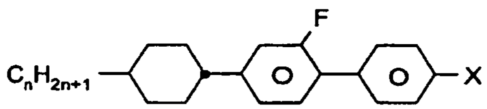
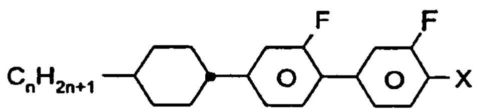
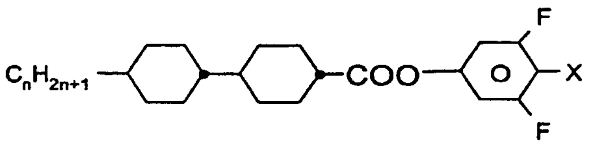


CGP-n-X
(X = F, Cl, OCF3)



CGG-n.FX
(X = F, Cl, OCF3)



CCZU-n-X
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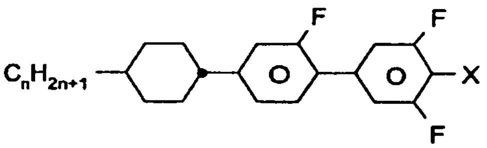

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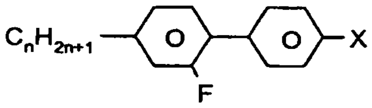

GP-n-X
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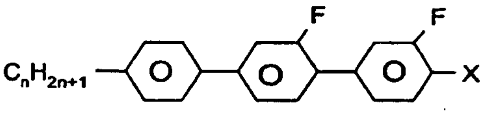
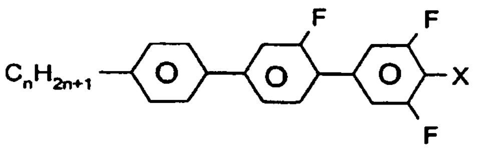
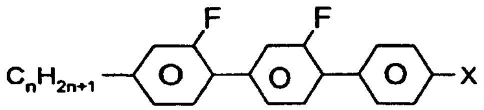
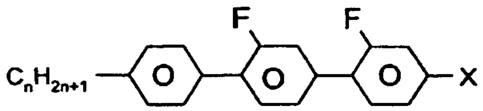




PGG-n-X
(X = F, Cl, OCF3)

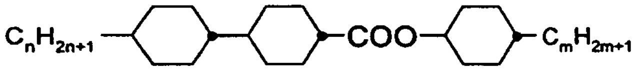
PGU-n-X
(X = F, Cl, OCF3)





GGP-n-X
(X = F, Cl, OCF3)

PGIGI-n-X
(X = F, Cl, OCF3)



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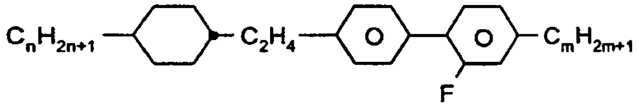

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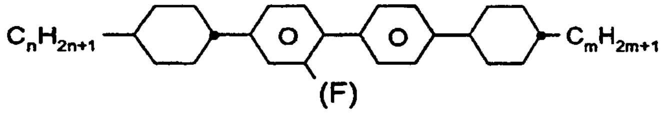

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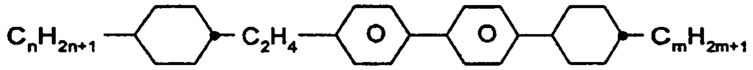
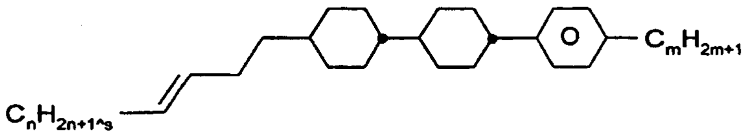
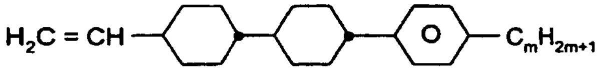


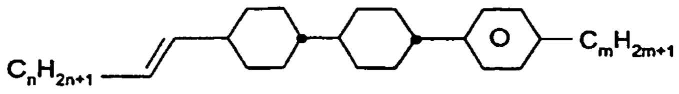
ECBC-nm



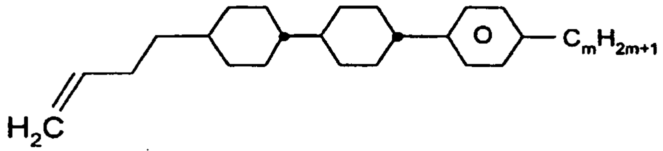
CCP-nV2-m



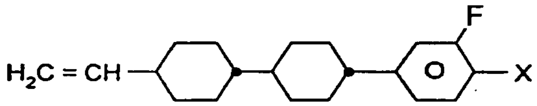
CCP-V-m



CCP-nV-m

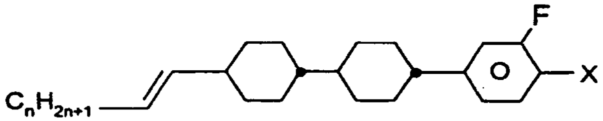


CCP-V2-m



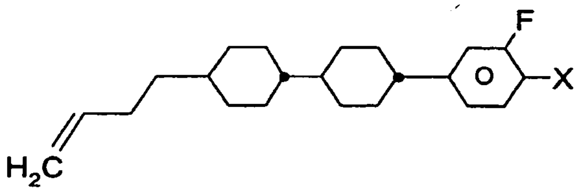
CCG-V-X

(X = F, Cl, OCF3)



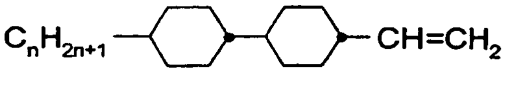
CCG-nV-X

(X = F, Cl, OCF3)

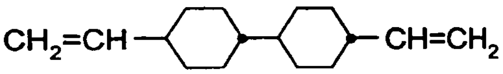


CCP-V2-X

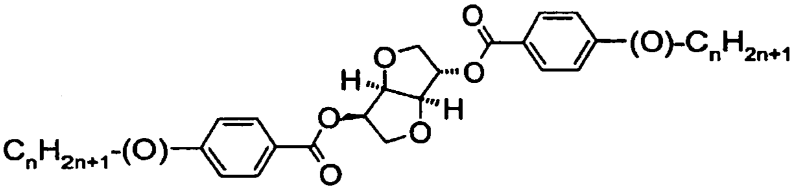
(X = F, Cl, OCF3)



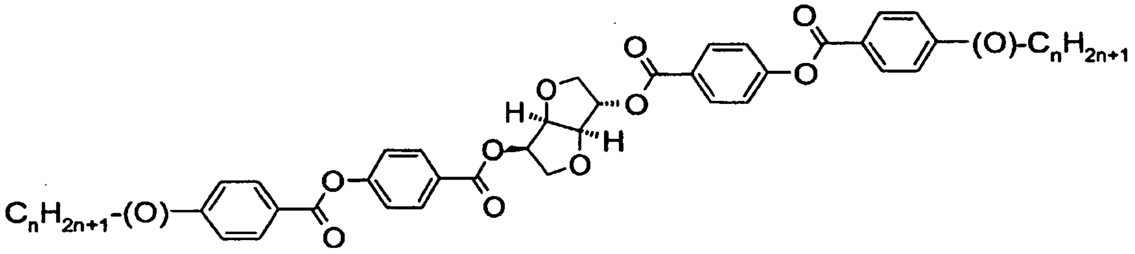
CC-n-V



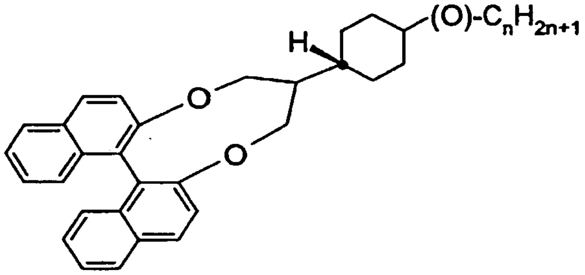
CC-V-V



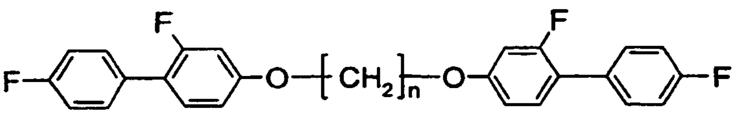
(n(O)-PZ)$_2$X*



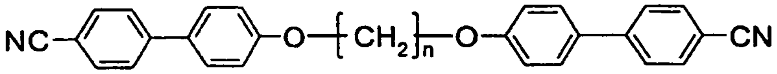
(n(O)-PZPZ)$_2$X*



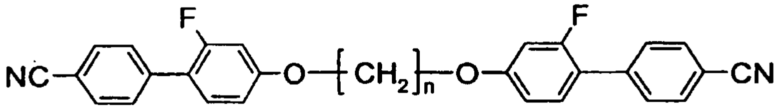
n(O)-C1(1O)$_2$N*



n(OGP-F)$_2$



n(OPP-N)₂



n(OGP-N)₂

The liquid crystal media according to the instant invention do contain preferably

- three or more, preferably fiive or more compounds, preferably of different formulae, selected from the group of compounds of formulae of tables A and B and/or
- one, two, three or more, preferably three, four or more compounds, preferably of different formulae, selected from the group of compounds of formulae of table A and/or
- one , two, three or more, preferably two, three or more compounds, preferably of different formulae, selected from the group of compounds of formulae of table B.

Examples

The examples given in the following are illustrating the present invention without limiting it in any way.

However, they illustrate typical preferred embodiments. They show the use of typical and preferred constituents and exemplarily illustrate their concentrations. Further they show possible variations of the phyiscal properties of the compositions, illustrating to the expert which properties can be achieved and in which ranges theiy can be modified. Especially the combination of the various properties which can be preferably achieved is thus well defined for the expert.

Comparative example 1

3% of the optically active isosorbide compound $(1OPZPZ)_2X^*$ are added to 97% of the dielectrically positive nematic mixture ZLI-4792, available from Merck KGaA, Darmstadt, Germany. The resultant mixture is called mixture A.

The mixture ZLI-4792 has the properties given in the following table 1.

Table 1: ZLI-4792

Physical Properties of ZLI-4792			
T(N,I)	=	92.6	°C
Δn (20 °C, 589.3 nm)	=	0.0969	
Δε (20 °C, 1 kHz)	=	5.3	
γ_1 (20 °C)	=	133	mPa·s
V_{10},TN (20°C)	=	1.95	V

The chiral dopant $(1OPZPZ)_2X^*$induces a cholesteric pitch of 0.292 µm at a concentration of 3.0% in a pure bimesogenic system consisting of 50% each of $7(OGP\text{-}F)_2$ and $9(OGP\text{-}F)_2$ (mixture C-0, see comparative example 3). This corresponds to a helical twisting power (HTP) of 114 μm^{-1}.

The resultant mixture of the dopant in ZLI-4792 has a favourably wide range of the chiral nematic phase. This mixture is investigated in a test cell with a cell gap of 5.0 µm. The cell has hybrid alignment, i.e. the alignment on one surface is homogeneous (planar) and on the other surface is homeotropic (perpendicular to the plane). One of the major surfaces of the cell is treated with the polyimide AL1051 of Japan Synthetic Rubber, Japan, which is imparting homogeneous orientation to the liquid crystal material, whereas the other major surface is treated with RN-783 from Nissan Chemicals, Japan, which is leading to a homeotropic orientation of the liquid crystal material. The uniform orientation of the liquid crystal mixture in the cell is achieved by application of an electrical field, the voltage typically being in the range from 5 V to 30 V at a reduced temperature of 0.968. During application of the voltage the sample is sheared by moving one substrate relative to the other in order to induce a preferred orientation.

The mixture is investigated at a reduced temperature of T/T(N,I)=0.968, wherein the temperatures are given in Kelvin. The results of the twist angle as a function of the applied electric field is shown in figure 1 and the other results are summarised in table 2 below. As, however, the value of $\Delta\varepsilon$ this mixture of 5.3 is rather high, already at an electric field strength of about 1.8 $V \cdot \mu m^{-1}$ helix unwinding is observed and the desired electro-optical effect is no longer achieved. Thus the maximum achievable angle of rotation is about 3° only, which is insufficient to achieve a good contrast in most typical electro-optical switching elements.

Table 2a: Results for example 1 and comparative examples 1 to 3

Example	Mixture	$\Delta\varepsilon$	ēP_0/K	P_0 / µm
Comp. 1	A-1	≈5	0.18	≈0.46
Comp. 2	B-1	≈0.1	0.06	≈0.46
Comp. 3	C-1	≈0.3	0.28	0.29
Ex. 1	D-1	≈1	0.04	0.56

Table 2b: Results for example 1 and comparative examples 1 to 3

Example	Mixture	V_c / V	V_{op} / V	$\Phi(V_{op})$ / °
Comp. 1	A-1	≈ 15	10	≈ 3
Comp. 2	B-1	>100	64	≈ 6
Comp. 3	C-1	> 70	70	≈33
Ex. 1	D-1	> 60	60	≈ 4

Comparative example 2

3% of the optically active compound $(1OPZPZ)_2X^*$, used in comparative example 1, are added to 97% of the dielectrically neutral nematic mixture ZLI-3086, available from Merck KGaA, Darmstadt, Germany. The resultant mixture is called mixture B-1.

The mixture ZLI-3086 has the properties given in the following table 3.

Table 3: ZLI-3086

Physical Properties of ZLI-3086			
T(N,I)	=	72	°C
Δn (20 °C, 589.3 nm)	=	0.1131	
Δε (20 °C, 1 kHz)	=	0.1	

To 97% of this mixture 3% of the ciral substance $(1OPZPZ)_2X^*$, used in Comparative example 1, have been added. The resultant mixture, mixture B-1 has a also a suitably wide range of the nematic phase, a suitable birefringence and a low value of Δε. This low value of Δε is favourabe as it prevents helix unwinding of the up to high applied voltages, but it renders mixture B difficult to be aligned under an applied electrical field with an easily accessible field strength.

This mixture, mixture B-1 is investigated too as described in comparative example 1. The results are shown in figure 1 and in table 2 above. This mixture, mixture B-1 has a favourably high value of the critical voltage for the unwinding of the cholesteric helix, but, probably due to it's low dielectrical anisotropy, the maximum achievable angle of rotation is rather low, even at high applied voltages.

Comparative example 3

A liquid crystal mixture, mixture C-0 is realized with the composition and properties given in the following table 4.

Table 4: Liquid crystal mixture C-0

Composition			Physical Properties			
Compound			T(N,I)	=	54.9	°C
No.	Abbreviation	Conc. /%				
1	$7(OGP\text{-}F)_2$	50.0	Δε (20 °C, 1 kHz)	=	0.3	
2	$9(OGP\text{-}F)_2$	50.0				
Σ		100.0				

To 97% of this mixture C-0 3% of the chiral compound $(1OPZPZ)_2X^*$, used in Comparative example 1, have been added. The resultant mixture, mixture C-1 has a range of the chiral nematic phase just barely sufficiently wide for some selected applications. The results of the investigation of this mixture are shown in figure 1 and in table 2 above. Obviously the mixture C-1 allows to generate an sufficiently large angle of rotation at technically accessible voltages. It, however has only a narrow range of the chiral nematic phase unsuitable for most practical applications.

Example 1

A liquid crystal mixture, mixture D-0 is realized according to the first preferred embodiment of the instant invention, with the composition and properties given in the following table 5.

Table 5: Liquid crystal mixture D-0

Composition			Physical Properties			
Compound			T(N,I)	=	89.5	°C
No.	Abbreviation	Conc. /%				
1	D-302FF	10.0	Δn (20 °C, 589.3 nm)	=	0.1383	
2	D-502FF	10.0				
3	CCP-302FF	5.0	Δε (20 °C, 1 kHz)	=	1.1	
4	CCP-502FF	6.0				
5	PCH-502FF	12.0				
6	CCP-21FF	6.0				
7	CCP-31FF	6.0				
8	CH-43	7.0				
9	PTP-201	6.0				
10	PTP-301	6.0				
11	CPTP-301	4.0				
12	CPTP-303	4.0				
13	CBC-53F	3.0				
14	PCH-3	8.0				
15	PDX-5	7.0				
Σ		100.0				

This mixture D-0 has a favourably broad range of the nematic phase, a moderately positive value of the dielectric anisotropy and a suitably high value of Δn.

Example 1a

To 97% of this mixture D-0 3% of the chiral substance $(1OPZPZ)_2X^*$, used in Comparative example 1, are added. The rsultant mixture, mixture D-1 is investigated as described in comparative example 1. The results are shown in figure 1 and in table 2 above.

The phase range of this mixtue is excellent and suitable for most practical applications. Further the mixture is easily oriented by the application of an electrical field and, at the same time, has a sufficiently high value of the critical voltage for the unwinding of the cholesteric helix.

Example 1b

To 98% of the mixture D-0 2% of the chiral binaphthol compound $(3C1(1O)_2)N^*$ are added. The resultant mixture, mixture D-2 has a sufficiently wide range of the chiral nematic phase. It is investigated like like mixture D-1 described above and leads to comparably favourable results. The angle of rotation achievable with mixture D-2 is even slightly larger than that of mixtures D-1 and even B-1.

Example 2

A further liquid crystal mixture, mixture E-0 is realized according to the second preferred embodiment of the instant invention, with the composition and properties given in the following table 6.

Table 6: Liquid crystal mixture E-0

Composition			Physical Properties			
Compound			T(N,I)	=	91.4	°C
No.	Abbreviation	Conc. /%				
1	D-302FF	10.0	n_e (20 °C, 589.3 nm)	=	1.6157	
2	D-502FF	10.0	Δn (20 °C, 589.3 nm)	=	0.1301	
3	CCP-302FF	6.0				
4	CCP-502FF	6.0	$\varepsilon_{\|\|}$ (20 °C, 1 kHz)	=	8.7	
5	PCH-502FF	12.0	$\Delta\varepsilon$ (20 °C, 1 kHz)	=	0.6	
6	CCP-21FF	8.0				
7	CCP-31FF	8.0				
8	CH-43	7.0				
9	PTP-201	5.0				
10	PTP-301	5.0				
11	CPTP-301	3.0				
12	CPTP-303	3.0				
13	CBC-53F	3.0				
14	PCH-3	7.0				
15	PDX-5	7.0				
Σ		100.0				

This mixture, mixture E-0 has a sufficiently wide range of the nematic phase, a favourably high value of Δn and, most important, a value of Δε high enough for dielectric orientation and sufficiently low to prevent unwinding of th echolesteric helix already at moderate electrical fields.

Example 2a

To 97% of this mixture E-0 3% of the chiral substance $(1OPZPZ)_2X^*$, used in Comparative example 1, are added. The resultant mixture, mixture E-1 is investigated as described in comparative example 1. The results are comparable to those obtained for mixture D-1 described in example 1a.

Example 2b

To 98% of the mixture E-0 2% of the chiral compound (3C1(10)$_2$)N*, used in example 1b, have been added. The resultant mixture, mixture E-2 has a sufficiently wide range of the chiral nematic phase. It is investigated like mixture D-2 and shows comparable, favourable properties, similar to those of mixture D-2 shown in example 1b.

Example 3

A liquid crystal mixture, mixture F-0 is realized according to the second preferred embodiment of the instant invention, with the composition and properties given in the following table 7.

Table 7: Liquid crystal mixture F-0

Composition			Physical Properties
Compound			T(N,I) = 88.8 °C
No.	Abbreviation	Conc. /%	
1	7(OGP-F)$_2$	11.0	
2	9(OGP-F)$_2$	44.0	
3	CCZU-2-F	4.0	
4	CCZU-3-F	10.0	
5	CCZU-5-F	4.0	
6	CCP-20CF3	7	
7	CCP-30CF3	6	
8	CCP-50CF3	6	
9	CH-43	5	
10	CBC-33F	3.0	
Σ		100.0	

To 98% of the mixture F-0 2% of the chiral compound (3C1(10)$_2$)N*, used in example 1b, have been added. The resultant mixture, mixture F-2 has a sufficiently wide range of the chiral nematic phase. It is investigated like mixture D-2 in example 2b at a temperature of 30°C. The results are shown in the following table 8.

Table 8: Results for examples 3 to 5

Example	Mixture	Δε (mixt. X-0)	V_c / V	Φ(45V) / °	ē/K / $C \cdot N^{-1} \cdot m^{-1}$
Ex. 3	F-2	3.8	67.5	10.5	0.40
Ex. 4	G-2	3.0	>90	14.5	0.6
Ex. 5	H-2	2.3	93	11.4	0.4

The measurements of this table are all performed at a temperature of 30°C. The values of dielectric anisotropy, given in Table 8, are obtained for a temperature of 20°C.

Example 4

A further liquid crystal mixture, mixture G-0 is realized according to the second preferred embodiment of the instant invention, with the composition and properties given in the following table 9.

Table 9: Liquid crystal mixture G-0

Composition			Physical Properties			
Compound			T(N,I)	=	76.3	°C
No.	Abbreviation	Conc. /%	T(Cr,N)	=	~20	°C
1	$7(OGP\text{-}F)_2$	14.0				
2	$9(OGP\text{-}F)_2$	56.0				
3	CCZU-3-F	7.0				
4	CCZU-5-F	4.0				
5	CCP-20CF3	4.0				
6	CCP-30CF3	6.0				
7	CCP-50CF3	6.0				
8	CBC-33F	3.0				
Σ		100.0				

To 98% of the mixture G-0 2% of the chiral compound $(3C1(10)_2)N^*$, used in example 1b, have been added. The resultant mixture, mixture G-2 has a reasonably wide range of the chiral nematic phase. It is investigated like mixture F-2 in example 3. The results are shown in table 8 above.

Example 5

A further liquid crystal mixture, mixture H-0 is realized according to the second preferred embodiment of the instant invention, with the composition and properties given in the following table 10.

Table 10: Liquid crystal mixture H-0

Composition			Physical Properties			
Compound			T(N,I)	=	79.3	°C
No.	Abbreviation	Conc. /%				
1	$7(OGP-F)_2$	11.0				
2	$9(OGP-F)_2$	44.0				
3	CCZU-3-F	7.0				
4	CCP-30CF3	7.0				
5	CCP-50CF3	6.0				
6	D-302	7.0				
7	CC-5-V	12.0				
8	CBC-33F	3.0				
9	CBC-53F	3.0				
Σ		100.0				

To 98% of the mixture H-0 2% of the chiral compound $(3C1(10)_2)N^*$, used in example 1, have been added. The resultant mixture, mixture H-2 has a sufficiently wide range of the chiral nematic phase. It is investigated like mixture F-2 in example 3. The results are shown in table 8 above.

Example 6

A further liquid crystal mixture, mixture I-0 is realized according to the second preferred embodiment of the instant invention, with the composition and properties given in the following table 11.

Table 11: Liquid crystal mixture I-0

Composition		
Compound		
No.	Abbreviation	Conc. /%
1	7(OGP-F)$_2$	5.0
2	9(OGP-F)$_2$	20.0
3	CCZU-3-F	7.0
4	CCP-30CF3	7.0
5	CCP-50CF3	6.0
6	CCG-V-F	10.0
7	D-302	8.0
8	CC-3-V1	11.0
9	CC-5-V	8.0
10	CCP-V-1	8.0
11	PTP-102	3.0
12	PTP-301	4.0
13	PTP-302	3.0
Σ		100.0

To 98% of the mixture I-0 2% of the chiral compound (3C1(10)$_2$)N*, used in example 1b, have been added. The resultant mixture, mixture I-2 has a sufficiently wide range of the chiral nematic phase. It is investigated like mixture F-2 in example 3.

Description of the figures

Figure 1 shows the dependence of the angle of rotation of the optical axis as a function of the appled electrical field for example 1 and comparative examples 1 to 3. The different symbols are representing the results for different mixtures. The open triangles are for mixture A-1, the full diamonds are for mixture B-1, the full squares are for mixture C1, the crosses are for mixture D-1.

Claims

1. A liquid crystal medium, characterized in that it comprises

   - a chiral component, component A,
   - optionally a bimesogenic component, component B,
   - a dielectrically positive component, component C,
   - optionally a dielectrically negative component, component D and
   - optionally a dielectrically neutral component, component E.

2. A liquid crystal medium according to claim 1, characterized in that it comprises

   - a dielectrically negative component, component D.

3. A liquid crystal medium according to at least one of claims 1 and 2, characterized in that it comprises

   - a bimesogenic component, component B.

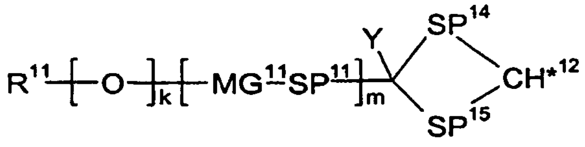
4. A liquid crystal medium according to at least one of claims 1 to 3, characterized in that it comprises a dielectrically neutral component, component E.

5. A liquid crystal medium according to at least one of claims 1 to 4, characterized in that it comprises both a dielectrically negative component, component D and a dielectrically neutral component, component E.

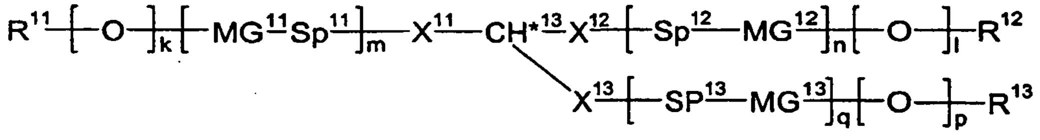
6. A liquid crystal medium according to at least one of claims 1 to 5, characterized in that it comprises component A which comprises

one or more compounds selected from the group of formulae I, I' and I"

$$R^{11}-\left[O\right]_k-\left[MG^{11}-Sp^{11}\right]_m-X^{11}-CH^{*11}-X^{12}-\left[Sp^{12}-MG^{12}\right]_n-\left[O\right]_l-R^{12} \qquad I$$



I'



$$R^{11}-\left[O\right]_k-\left[MG^{11}-Sp^{11}\right]_m-X^{11}-CH^{*13}\left(-X^{13}-\left[SP^{13}-MG^{13}\right]_q-\left[O\right]_p-R^{13}\right)-X^{12}-\left[Sp^{12}-MG^{12}\right]_n-\left[O\right]_l-R^{12}$$

I"

wherein

R^{11} R^{12} and R^{13}	are each, independently of one another, H, F, Cl, CN, NO_2, NCS, SCN, OCN, a stright chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH_2 groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH_3)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another or, in case they are not linked to an O atom, H,

SP^{11}, SP^{12} and SP^{13}	are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms, preferably an alkylen group, it beeing also possible for one or more CH_2 groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH_3)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, -CF_2- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another,
SP^{14} and SP^{15}	are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms,
X^{11}, X^{12} and X^{13}	are each, independently of one another, -O-, -S-, -CO-, -COO-, -OCO-, -OCOO-, -CO-NH-, -NH-CO-, -CH_2CH_2-, -OCH_2-, -CH_2O-, -SCH_2-, -CH_2S-, -CF=CF-, -CH=CH-, -OCO-CH=CH-, -C≡C- or a single bond,
k, l, n, m, p and q	each are 0 or 1,
m+n+q	is 1, 2 or 3,
MG^{11}, MG^{12} and MG^{13}	are each, independently of one another, a mesogenic group,
CH^{*11} and CH^{*12}	are, independently from each other, a chiral, bivalent group,
CH^{*13}	is a chiral, trivalent group.

7. A liquid crystal medium according to at least one of claims 1 to 6, characterized in that it comprises component B, which comprises one or more compounds of formula II

$$R^{21}-\left[-O-\right]_{i}-MG^{21}-SP^{2}-MG^{22}-\left[-O-\right]_{j}-R^{22} \qquad \mathrm{II}$$

wherein

R^{21}, R^{22}, MG^{21}, MG^{22}, SP^{21}, and SP^{22},

independently of each other, have the respective meanings given for R^{11}, MG^{11} and SP^{11}, respectively in claim 1,

i and j are, independently of each other, 0 or 1.

8. A liquid crystal medium substantially as hereinbefore described with reference to Examples 1 to 6.

9. A liquid crystal medium substantially as hereinbefore described with reference to and as shown in Figure 1.

10. A liquid crystal device, characterized in that it comprises a liquid crystal medium according to at least one of claims 1 to 9.

11. A liquid crystal device according to claim 10, characterized in that it is an electro-optical display.

12. Use of a liquid crystal medium according to at least one of claims 1 to 9 in a liquid crystal device.

Application No: GB 0226741.7
Claims searched: 1-7

Examiner: Dr Jonathan Corden
Date of search: 13 May 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1, 3, 10-12	GB 2356629 A	(MERCK) see abstract, page 4 lines 23-26, page 17 line 10-page 18 line 5, page 24 lines 1-11
X	1, 2, 4, 5, 10-12	GB 2327682 A	(MERCK) see abstract especially
X	1, 2, 4, 5, 10-12	GB 2322631 A	(MERCK) see abstract especially
X	1, 2, 4, 5, 10-12	DE 10030459 A	(MERCK) and also WPI Abstract Acc No. 2001-399129
X	1, 2, 4, 5, 10-12	DE 10020061 A	(MERCK) and also WPI Abstract Acc No. 2001-123983
X	1, 4, 10-12	DE 19720296 A	(MERCK) and also WPI Abstract Acc No. 1998-020157
X	1, 2, 10-12	JP 55069683 A	(NIPPON) and also WPI Abstract Acc No. 1980-48711C

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{V}:

C4X

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

C09K

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, PAJ